CarbonTracker - CH$_4$

GWP - the radiative forcing kg/kg relative to CO2 integrated over 100 years

CH4 contributes about half the radiative forcing of CO2 and is the largest non-CO2 anthropogenic

contribution to radiative forcing.

Hansen et al (2000) proposed that reductions in anthropogenic sources of methane could be made relatively easily

with significant reductions in radiative forcing and air quality improvements.

	CO_2	CH_4
Fluxes We Estimate:	Terrestrial Biosphere Oceans	Coal Production, Oil/Gas Leaks Animals, Waste, Rice, Wetlands Termites, Oceans, Soils, Others
Fluxes We "Know":	Fossil Fuels	None
Photochemistry:	None	Reaction with OH (and Cl)
Measurement Sites	~100	<100

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Note that the sources of CH4 are not spatially excusive like the CO2 sources, they may overlap.

Also, the inventories are not necessarily as well-developed as the CO2 fossil fuel emissions. EDGAR- 2003, for example has not been released but was due in 2006!

Photochemistry: for CH4 we pre-defined OH, usually optimized against methyl chloroform. The OH fields don't vary interannually, although we plan to do an ensemble to test sensitivity to OH (working with collaborators in Europe and at GFDL) using a variety of model calculations.

For CO2, we have continuous data from tall towers as well as BRW and MLO. For CH4 we have continuous data only at BRW and MLO. Plans include continuous measurements at tall towers. We may also make use of the SCHIAMACHY data, and possibly AIRS in the future.
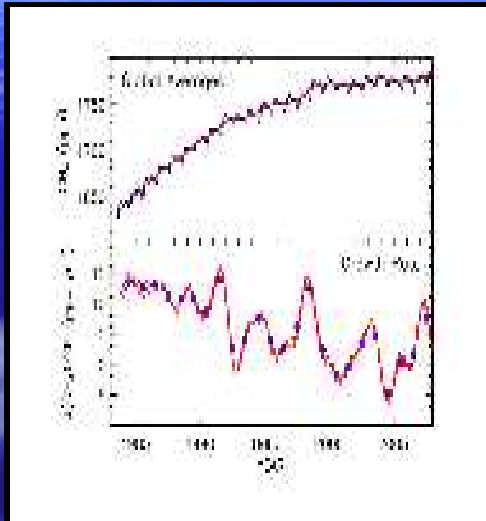
Optimized 2001 Emissions: 526Tg/yr
(*Bergamaschi,2002*)

Coal	30	(TgCH4/yr)
Oil/Gas	50	
Enteric Fermentation/Manure	100	
Rice	59	
Biomass Burning		32
Waste	74	
Wetlands		174
Wild Animals	5	
Termites	19	
Soil	-38	
Oceans	17	

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Large-region inversion results using TM3 and network observations (no SCHIAMACHY).
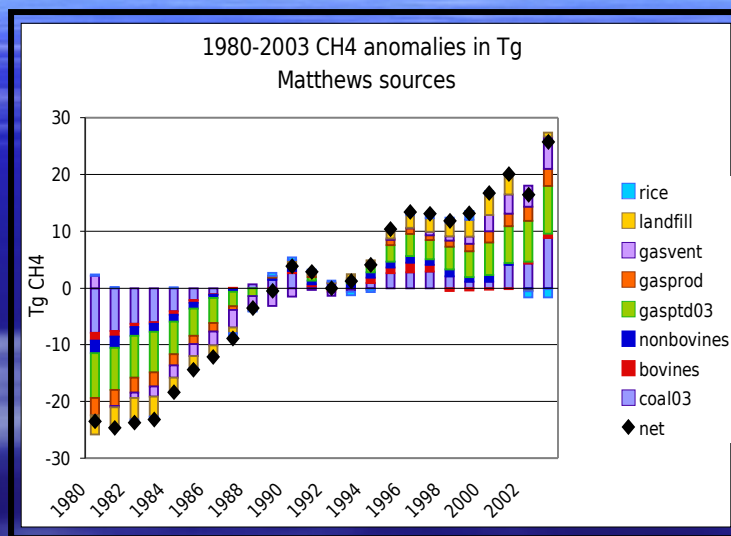
Observed Global Growth Rate

Methane could be approaching steady state (Dlugokencky et al., GRL, 2003) even though it is suspected that some sources are increasing.

Why is growth slowing?

What causes variability?

What happened in 2007?

Where Did It All Go?

1980-2003 CH4 anomalies in Tg
Matthews sources

These are anthropogenic sources. Wetlands may have decreased, especially in the tropics where inundation derived from satellite observations shows a small decreasing trend. Interestingly, a trend in the satellite inundation data at high latitudes isn't observed.
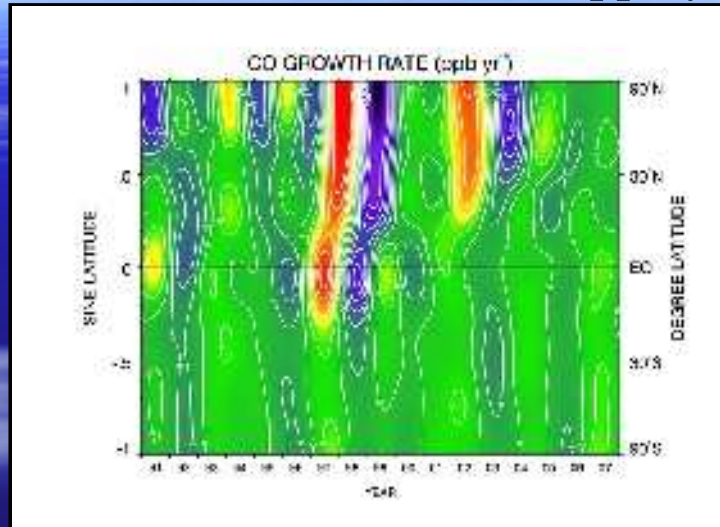
Observed CH$_4$ Growth Rate (ppb/yr)
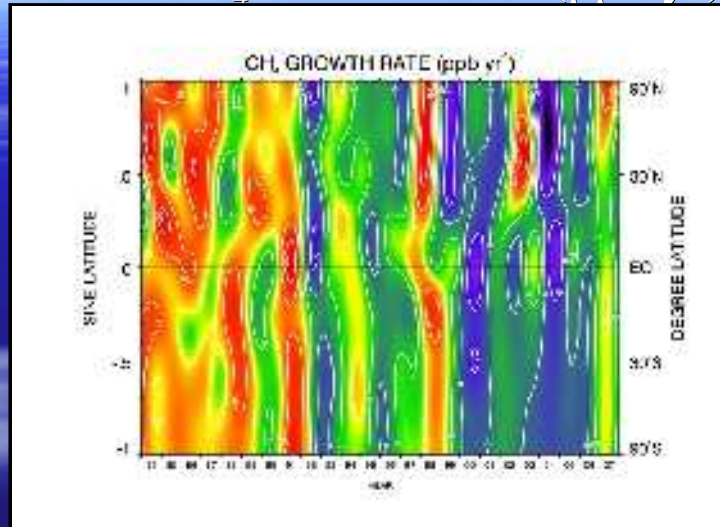
(Figure by K. Masarie)

Note rise to "steady-state". Note the large El Nino years (97-98, 02-03) that are also high biomass burning years. But 2007 wasn't an El Nino year - was there a lot of burning anyways?
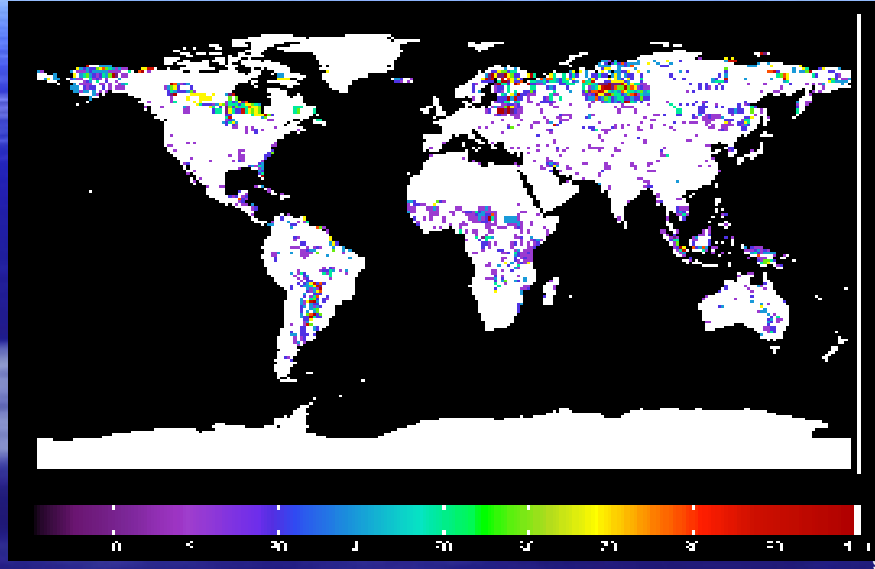
Observed CO Growth Rate (ppb/yr)

(data: P. Novelli)

Nope! It looks like the CH4 increase of 2007 was really due to increased wetland output associated with higher than normal temperature and precipitation.

Fractional Inundation (%) (Matthews and Fung)

This inventory was developed from aeronautical charts and was published in 1990. Use of this inventory assumes that the wetland distribution hasn't changed over the past couple of decades.

The satellite inundation data likely underestimates wetland extent because it sees only standing water. Many wetlands are saturated soil with vegetation.

Interestingly, the satellite inundation show a small trend in the tropics over the past two decades. Could this be balancing the increasing anthropogenic sources?

2007 Wetland Emissions(Annual Total)

Eurasia: 8Tg
N America: 3Tg

Tg CH$_4$

10
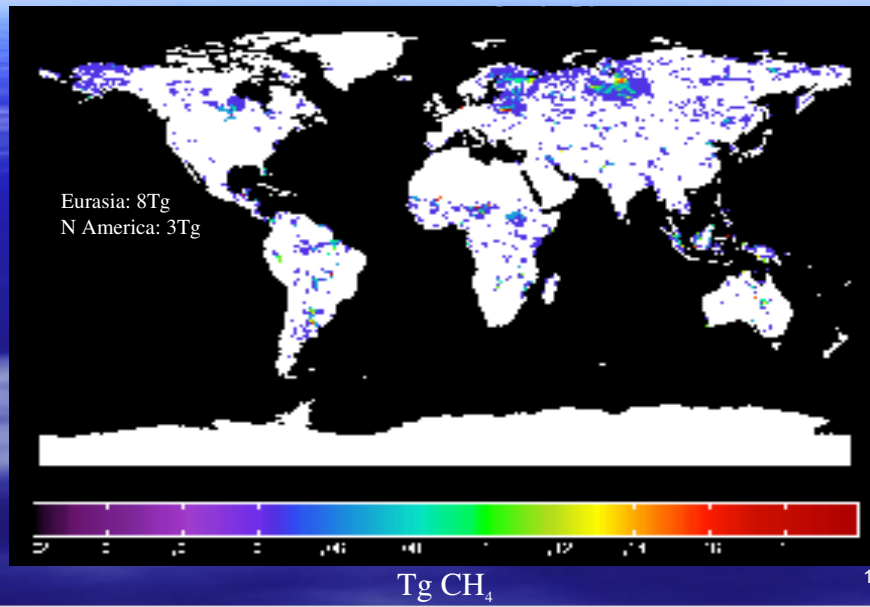
Modeled and Observed CH$_4$ Anomalies
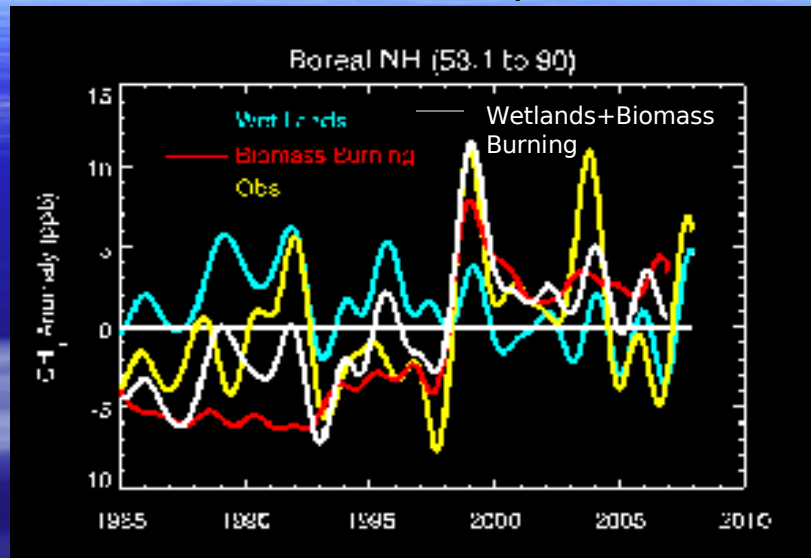
Note that the data are deseasonalized and high frequencies are filtered out. Also, the exponential approach to equilibrium

(long-term quadratic trend) is removed. The model calculations are treated in approximately the same way.

Also note that trend in temperatures over decades should lead to higher CH4 emissions from wetlands over the last several decades. Yet we don't see this in the data. Why not?

Estimates suggest that 500-900 PgC potentially reside in Arctic soils.

This will come out as CO2 or CH4 depending on hydrological conditions/ temperatures

3.8Tg/yr from Siberian lakes, 58% increase since mid-1970's (Walter et al., Nature, 2006)

Will future emissions from permafrost soils start to emerge gradually? Or will there be a threshold after which emissions will

abruptly increase?
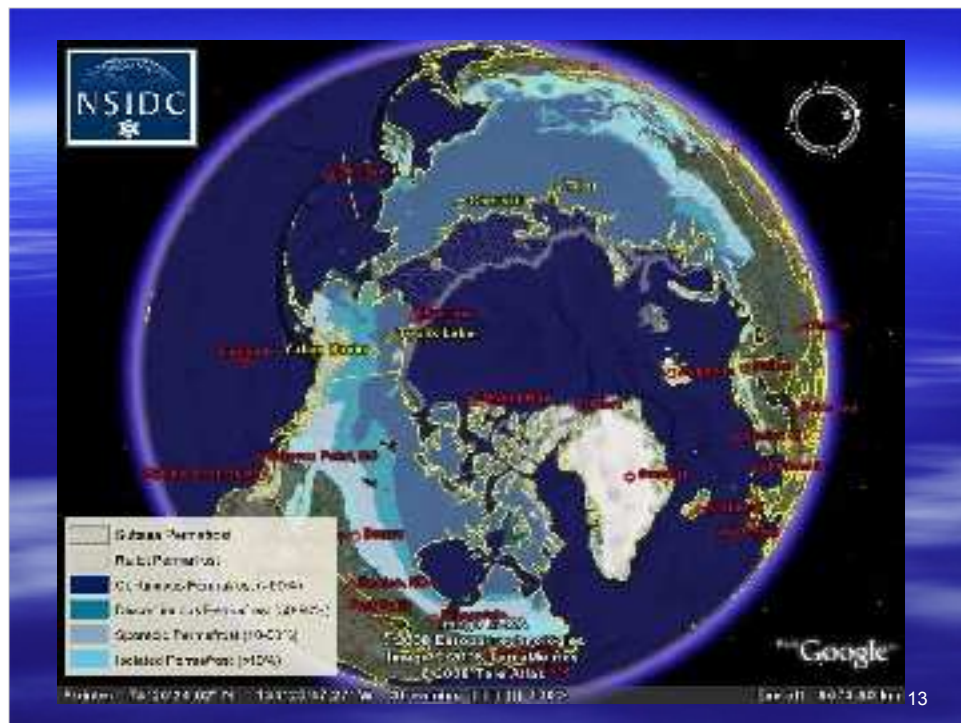
The sites in with yellow markers are the sites we're hoping to get continuous data from. We've recently started observations at Cherskii, but there haven't been resources to start the others.

But 2% is still ~10Tg!

(Source: S. Montzka, ESRL)
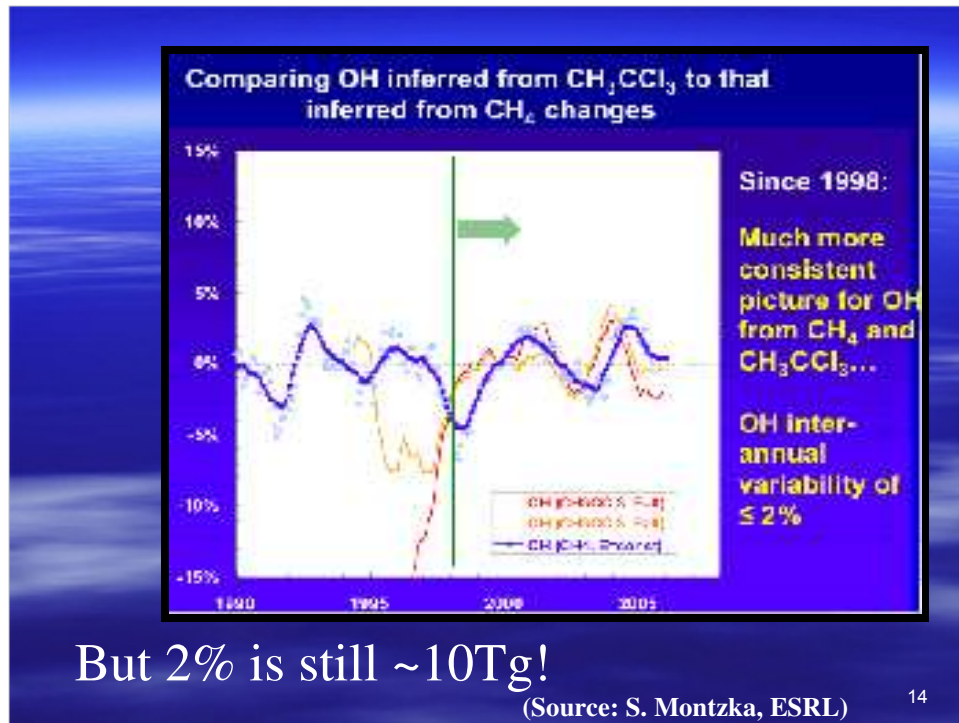
But this variability is still important when compared to processes that cause observed CH4 variability - 10Tg!

Also, the EnKF is a really good technique to use for weaking nonlinear systems like CH4 with photochemical loss.

Prototype CarbonTracker-CH$_4$: Priors

Bergamaschi et al. (2002) sources

- **Large region inversion using network obs.**
- **Coal, Oil/Gas**
- **Enteric Fermentation, Wild Animals, Termites**
- **Rice, Wetlands, Biomass Burning**
- **Waste**
- **Soil Uptake, Oceans**

Photochemical Loss
- **Repeating Seasonal Cycle, Optimized Using CH$_3$CCl$_3$**

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We're hoping to use improved prior modules. We will possibly use the Matthews sources, or the new EDGAR inventory when it becomes available. Also, we're working on improving a global wetland model for use with the CH4 assimilation.

We are also collaborating with the Natl. Snow and Ice Data Center to calculate emissions associated with thawing permafrost.

We hope to include interannual variability OH in the near future.

Prototype CarbonTracker-CH$_4$: Inverse

121 parameters (Scalar Multipliers of Fluxes)
 Land: 12 regions x 10 processes
 Ocean: 1 regions

Prior Uncertainty 75%

Sites 83 Active sites
 57 Surface sites
 24 Aircraft profile locations
 2 Observatories

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The uncertainties on the priors and the model-data mismatch errors were prescribed in a similar way to CarbonTracker-CO2. The same categories of sites were chosen (e.g. problem, marine boundary layer, etc.), and the variances were scaled for atmospheric CH4 abundances.
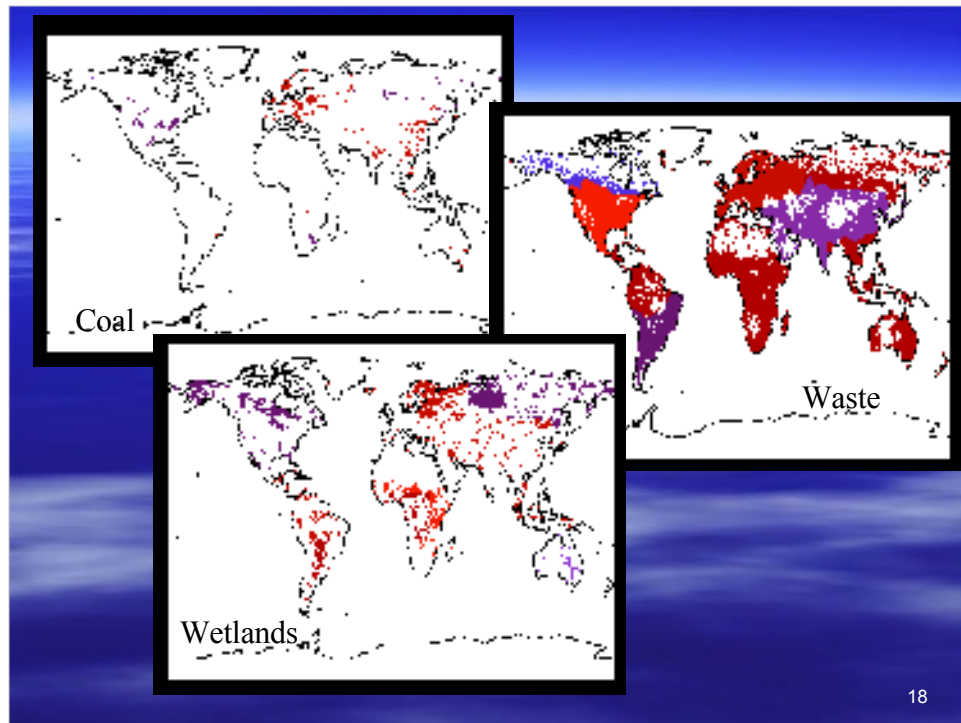
Co-Located Distributed and Point Sources

(Natl. Geographic, June 08)

This is a case of a diffuse source region with co-located point sources - a drilling pad on environmentally senstitive wetlands in

Western Siberia.

Coal

Waste

Wetlands

These figures illustrate the 1x1 grid cells containing each source. Note that each grid cell may contain more than one type of

source.

A source like coal is distribution over small regions that may be fairly isolated from each other. It is possible that the current

network may not be able to constrain a source like if no measurement sites are nearby. On the other hand, a source that is

spread over large areas will be constrained, but flux estimates may be biased due to uneven sampling of the source.

Conclusions

1) We need to track the sources/sinks of atmospheric methane because we don't understand its budget!

2) A prototype of CarbonTracker-CH_4 exists and is being evaluated.

3) Work is proceeding on developing/identifying improved models for prior fluxes.

4) CarbonTracker-CH4 could provide an early indication of methane release from destabilizing Arctic permafrost.
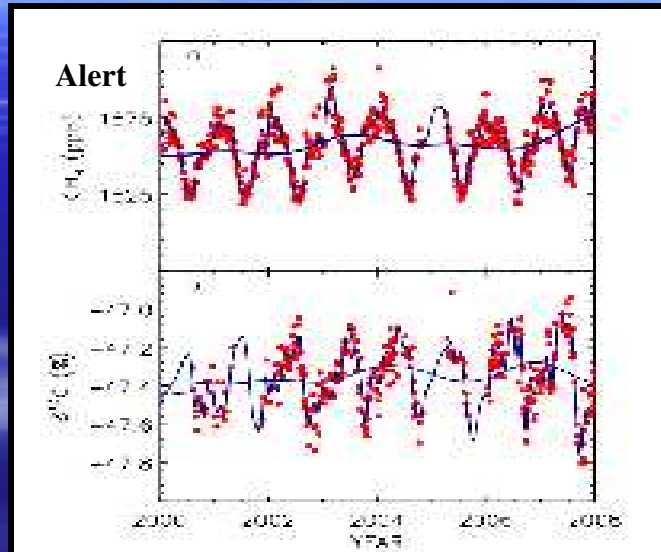
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Wetland Emission Module
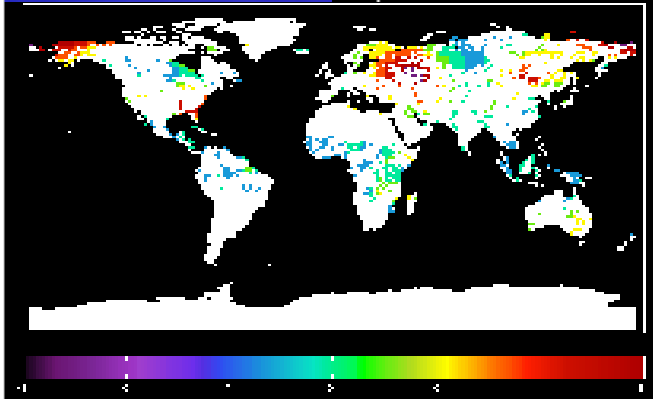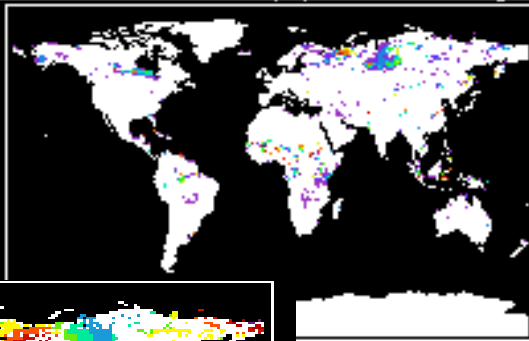
mm/month

°C

August 2007

The CH4 Isotope Data Supports the Wetland Hypothesis for 2007

Note that the data are deseasonalized and high frequencies are filtered out. Also, the exponential approach to equilibrium

Removed. The model calculations are treated in approximately the same way.